Responses of Heathland *Antechinus stuartii* to the Royal National Park Wildfire in 1994

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Little is known of the detailed responses of mammal populations to wildfires. Mortality is commonly observed, but trapping studies frequently record that animals have survived the passage of a fire front only to succumb to various causes of mortality thereafter. In particular, previous studies of *Antechinus stuartii* have reported population declines to near zero soon after fire. This study followed an *A. stuartii* population for over a year following the January 1994 wildfire at Royal National Park, between Sydney and Wollongong, New South Wales. The population was sustained through 1994, with many animals recaptured on successive trapping periods. There was successful reproduction in October 1994 to produce a second generation that was sampled in a May 1995 trapping session. We propose that the sustaining of this population, rather than its disappearance (expected based on previous studies), may have been permitted by two factors: (i) the extensive use by these animals of the many rock outcrops in the study area, for foraging, cover and nesting sites (determined by spooling animals), and (ii) the presence of a large energy source in the form of *Xanthorrhoea* nectar throughout the winter of 1994, produced by the fire-stimulated flowering of *X. media*. Pollen from *Xanthorrhoea* was present in the scats of almost all animals sampled and almost all flowering stalks showed evidence of having been climbed by small mammals during the flowering period. The timing of fire determines whether *Xanthorrhoea* will flower in the year immediately following fire or not until the subsequent winter. Thus populations of some small mammals may respond to the timing of fire via the responses of the flora

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INTRODUCTION

Fires are commonly believed to cause the deaths of vertebrate fauna, especially fires of high intensity (Whelan 1995). Observations that lead to this belief include the finding of charred carcasses after fires and failure to find animals in recently burned vegetation. Hemsley (1967), for example, reported that carcasses of 59 bird species were washed up on beaches in Tasmania after a wildfire in *Eucalyptus* forest … an observation supported by observations made after a wildfire at Nadgee Nature Reserve in New South Wales (Recher and Christensen 1981).

In contrast, some studies have reported good survival of fire by vertebrates. For example, Christensen (1980) radio-tracked 19 woylies (*Bettongia penicillata*) during and after high-intensity prescribed fire in south western Australian eucalypt forest. Six of the 19 survived in unburnt patches, nine survived by doubling back through the flames, and four hid in logs. One of the four that sought refuge in logs was killed by suffocation. Many anecdotal observations of animals still alive soon after the passage of a high intensity fire support Christensen's findings (e.g. Newsome et al. 1975, Fox and McKay 1981).

The resolution to this apparent contradiction may be that many animals are able to survive the passage of the fire front, though some succumb, but that the surviving population crashes (or emigrates) soon after the fire (Christensen and Kimber 1975, Newsome et al. 1975, Cheal 1983, Whelan 1995). In particular, Fox (1982) found an absence of *Antechinus stuartii* during the first year after fire in heath at Myall Lakes National Park, north of Newcastle, with the population not increasing until more than two years after the fire. Newsome et al. (1975) found that an *A. stuartii* population in heath at Nadgee Nature Reserve declined to almost zero in heathland during the year after a December wildfire.

The reasons for population decline may include increased predation, shortage of food and changes in vegetation structure (Whelan 1995). It has been further suggested that a succession of small mammal species occurs as the flora recovers and the vegetation structure changes over time (Fox and McKay 1981, Higgs and Fox 1993).

Unburned patches of vegetation and other refuges may provide opportunities for survival of the passage of a fire front, as described above for the woylies studied by Christensen. Newsome et al. (1975), for example, indicated that unburned stream-side vegetation at Nadgee Nature Reserve may have permitted survival of some *Antechinus* individuals and immediate re-establishment of the population after fire in that habitat.

There has been very little detailed study of the importance of unburned patches of vegetation for survival of fires by small mammals, and too little is known of the importance of post-fire habitat in permitting continued occupation of a burned site. The January 1994 wildfire in Royal National Park provided an opportunity to study short- and medium-term survival of *Antechinus stuartii* in a heathland site.

Antechinus stuartii is a widespread small mammal species, occurring in many habitats throughout east, and south east Australia. It is easily trapped and is often common, making it a suitable species for study. It consumes a wide range of both arboreal, and ground-dwelling arthropods, some plant material, nectar, and occasionally vertebrates (Hall 1980, Dickman 1983, Green 1989, Goldingay et al. 1991). Social interaction is common, and communal nests may be found in hollows in trees, rock crevices, and logs (Hyett and Shaw 1980, Cockburn and Lazenby-Cohen 1992).

This study used the opportunity of the high-intensity fire in heathland at Royal National Park to examine the following:

(i) change in *Antechinus stuartii* population after fire;
(ii) potential importance of structural features of the habitat (rock outcrops, unburned patches of vegetation) for *Antechinus stuartii* activity;
(iii) availability and use of some food resources over the winter period.

METHODS

Study area

This study was initiated in the Royal National Park (34°08'S, 151°04'30"E) about a month after the wildfire in January 1994. The fire burned through approximately 95% of the 17,163 ha National Park. The study area was located in open heathland towards the northern end of the Park.

Trapping was also located in a nearby site of similar vegetation that was not burned in the 1994 fires. The Cataract Catchment site (34°16'30"S, 150°53'54"–150°55'E) is 22 km from the Royal National Park site. No appropriate unburnt areas were available in the Royal National Park.

Prior to the 1994 fire in the Royal National Park, the two areas were similar in their fire histories. The Cataract Catchment sites were burnt in a fire in December 1990, and in a hazard reduction burn in 1982 (George Williams, pers. comm.). The Royal National Park sites were last burnt in by a wildfire in the 1987/88 fire season, and before that by a prescribed burn in 1977/78.

The January 1994 fire in Royal National Park occurred during hot, dry, windy weather conditions. These weather conditions, the consumption of all leaf litter by the fire, the presence of white ash on the ground, and the reduction of most plants in the burnt area to charred stems, all suggest that the fire in the heathland was of high intensity.

Small patches of unburned vegetation were scattered throughout the study area (Figure 1). These were extremely variable in both size and shape. They were sometimes associated with sandstone rock outcrops.

Trapping was conducted in four main periods at Royal National Park: (i) March to May 1994 (1185 trap-nights); (ii) June to July 1994 (880 trap nights); (iii) October 1994 (399 trap-nights); and (iv) May 1995 (360 trap-nights). Trapping was conducted in the Cataract Dam catchment only in March–May 1994 (400 trap-nights) and October 1994 (160 trap-nights).

Site Selection

Trapping grids were established in four types of sites:

(i) heathland vegetation that had no rock outcrops and was entirely burned (open-burned: sites 1 & 7);
(ii) no rock outcrops but with a patch of unburned vegetation (open-patch: sites 2 & 5);
(iii) vegetation with rock outcrops but the vegetation was entirely burned (rock-burned: sites 4 & 8);
(iv) rock outcrops and a patch of unburned vegetation (rock-patch: sites 3, 6 & 9).

Sites were chosen so that patches of unburned vegetation within them were roughly comparable in size, to reduce variations in capture rates due to the size of the patch.

Trapping grids were set up at five sites in the Cataract catchment, using locations of similar topography and vegetation to the Royal National Park area pre-fire.

Trapping Methods

A trapping grid was marked in each site. In sites 1–8, grids comprised 5 lines of 8 traps, with traps approx. 10 m apart. Site 9 was the only site that contained a large area of unburned vegetation as well as substantial rock outcrops. This was the site used for the studies of *Antechinus* movements (see below). Trapping here initially comprised 6 rows of 10 traps about 15 m apart, later increased to 80 traps. In June 1994, trapping at site 8 was also increased to 80 traps, by establishing a second grid of 40 traps on the rock outcrop (see'8b' on Figure 1).

Bait used in traps was a mixture of oats, peanut butter, and honey. A mixture of small (22 x 8.5 x 8 cm) and larger (33 x 10 x 9 cm) Elliott traps was used. Traps were always washed after a capture. Traps were set out as close to dusk as was feasible and were checked at dawn or soon after. Animals were tagged by toe-clipping.

Scat Samples

Scats deposited by animals in traps during trapping sessions from May to October 1994 were collected and placed in 70% ethanol for later microscopic examination. Approximately 0.03g (air-dry weight) from each scat was mixed in a droplet of water on a microscope slide. *Banksia* and *Xanthorrhoea* pollen grains were counted in ten scans (400 x magnification) from edge to edge of the cover slip (17.5 mm). Three categories were used for the total pollen grain count for a slide: 0; 1–19; ≥20 pollen grains.

A total of 35 scat samples was collected from The Royal National Park sites: 19 from males and 16 from females: 15 were collected from animals trapped in unburned patches (Sites 2, 3, 5, 6, 9) and 20 from animals trapped in the burned sites. At Cataract Catchment, 7 samples were from males and 7 from females. All these scat samples were scored for *Banksia* pollen. However, some samples were taken before *X. media* had started flowering in Royal National Park, so the only samples scored for *Xanthorrhoea* pollen were those collected during the flowering period: 12 in patches and 10 in burned sites.

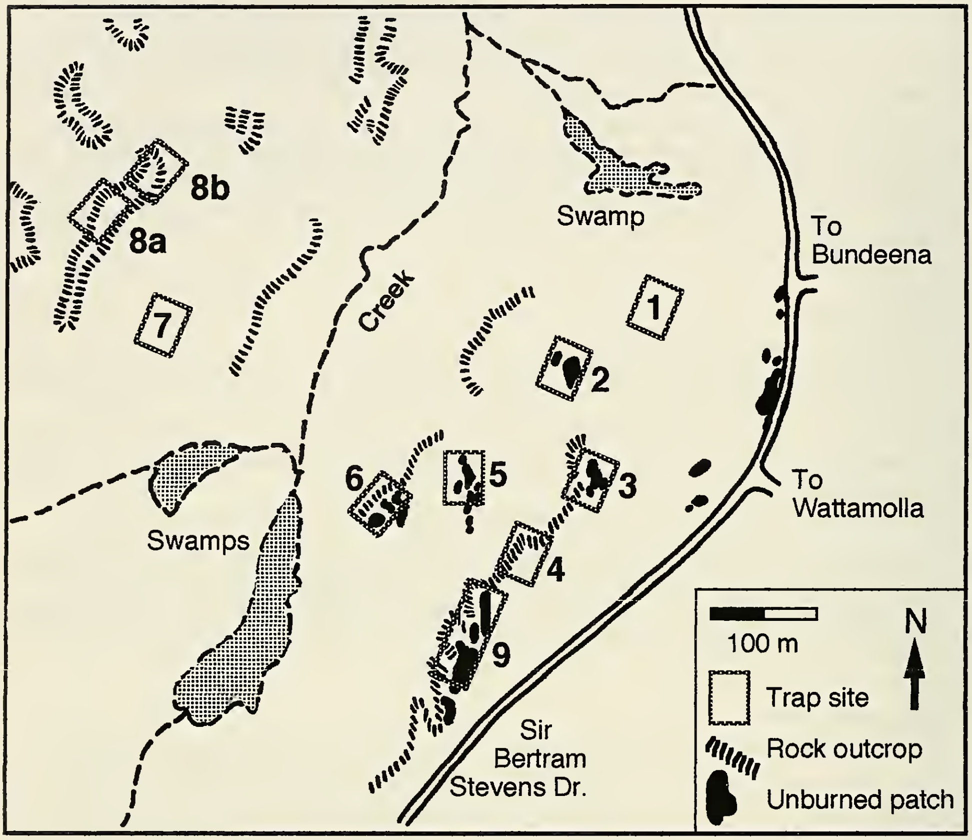


Fig. 1. Map of study sites at Royal National Park, showing locations of trapping grids (numbered 1–9), rock outcrops and unburned patches of heath vegetation.

Antechinus movements

Detailed movements of seven *Antechinus* individuals were recorded in site 9, Royal National Park, between March and May 1994, using the spool-and-line tracking technique (see Carthew 1993). Elliott traps were situated close to flowering *Banksia* plants (*B. ericifolia* and *B. marginata*) and small rock crevices. Traps were set late in the afternoon and checked at dawn. *Antechinus* individuals captured were fitted with a spool of fine thread (nylon quilting thread bobbin 70/2 — Penguin Threads Pty. Ltd., Prahran, Victoria) containing 165 m of thread. The spools, which unravel from the middle, were covered in plastic tape to avoid snagging on vegetation. Spools were stuck to the tips of the fur on the shoulders of the animals with Superglue, and the loose end was secured at the point of release. Threads were followed within 36 hours of release of an animal, and the route was plotted in relation to landmarks within the study site. Only five of the seven spooling attempts were successful.

Antechinus visits to *Xanthorrhoea*

Xanthorrhoea media has a fine white powder on the surface of its flowering stalk. Disturbance of this powder, for example perching by birds or climbing by mammals (even human fingerprints) leaves a long-term record on the stalk. We considered that small mammals, such as *Antechinus stuartii*, may climb flowering stalks to obtain nectar from inflorescences (see Goldingay et al. 1991).

The percentage of flowering stalks used by small mammals was estimated by scoring the percentages of flowering stalks with 'scurry marks' in ten 20 x 20 meter quadrats. This section of field work was conducted on the 11th of September 1994; towards the end of the flowering season for *X. media*.

RESULTS

Species captured

Five species of small-mammals were caught after the fire in the Royal National Park: *A. stuartii, M. musculus* (house mouse), *R. fuscipes* (bush rat), *R. lutreolus* (swamp rat), and *Cercartetus nanus* (Eastern pygmy possum). Only two individuals of *C. nanus* were caught; both in the largest of the patches of unburned vegetation (site 9). Only two species were caught in the Cataract Dam catchment area: *A. stuartii* and *R. lutreolus.*

Capture rates of *A. stuartii*

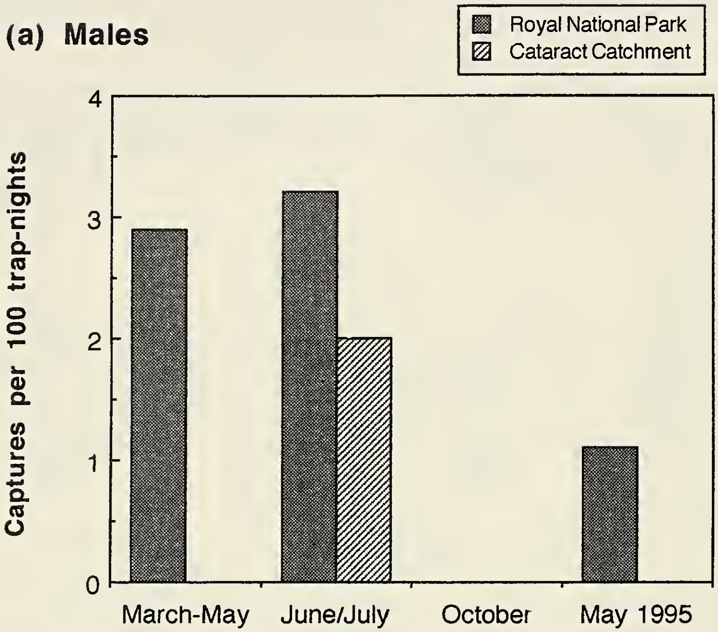
Over all four trapping sessions at Royal National Park, 20 male and 24 female *A. stuartii* were captured. Numbers captured per 100 trap-nights remained quite consistent through the 1994 trapping periods at Royal National Park for both males and females (Figure 2). No males were caught in October 1994 in either study area, because all were dead after the breeding season (Figure 2a). Capture rates of both males and females had declined substantially by the May 1995 trapping period (Figure 2a & b): 38% of March–May 1994 for males and only 14.4% for females. The capture rate per 100 trap nights for males in Royal National Park was about 60% higher than that in the Cataract Dam sites, for the June to July trapping period (Figure 2a). Capture rates for female *A. stuartii* in the Cataract Dam area were higher than that in the Royal National Park, in both the June/July and the October trapping periods.

For both male and female *A. stuartii* in the Royal National Park, at least 60% of captures in the June to July and October 1994 trapping periods were recaptures of individuals initially caught in the March to May trapping period (Figure 3 a & b). No new animals were caught during the October 1994 trapping period, but all captures in May 1995 were new individuals, as would be expected from the 'annual' life history of this species.

The females with pouch young caught in the October trapping in the Royal National Park and the Cataract Dam were similar in age, with young from both populations being estimated as under 1 week old. A female without young, which appeared to be pregnant, was caught in the Cataract Dam on October 4. The number of young carried by females, excluding the female which appeared to be pregnant, was similar for the Royal National Park and Cataract Dam. In the Royal National Park 7 females had an average (±s.e.) of 7.9 (±0.14) young each, and in the Cataract Dam 4 females had an average of 7.5 (±0.50) young each.

Variation among capture sites at Royal National Park

Male *A. stuartii* showed no consistent difference in capture rates comparing open versus rock outcrop sites, or comparing burnt sites versus those with unburnt patches (Figure 4a). The highest capture rates for female *A. stuartii* were in sites with rock outcrops (Figure 4b) but two sites with both rock outcrops and unburned vegetation (sites 3 and 6) had low capture rates. The highest capture rates for female *A. stuartii* were recorded where the two largest rock outcrop sites were located (sites 8 and 9). Also, site 4, the site with the third highest capture rate of female *A. stuartii* was located close to site 9.



(a) Males

(b) Females

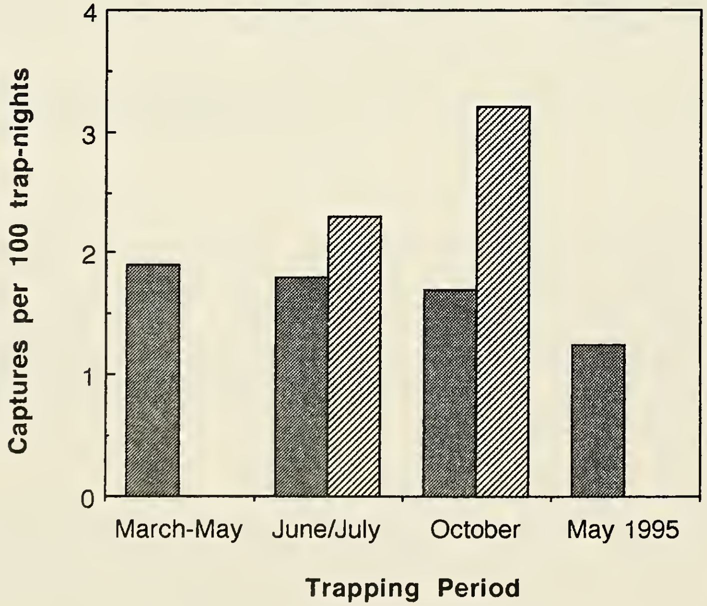
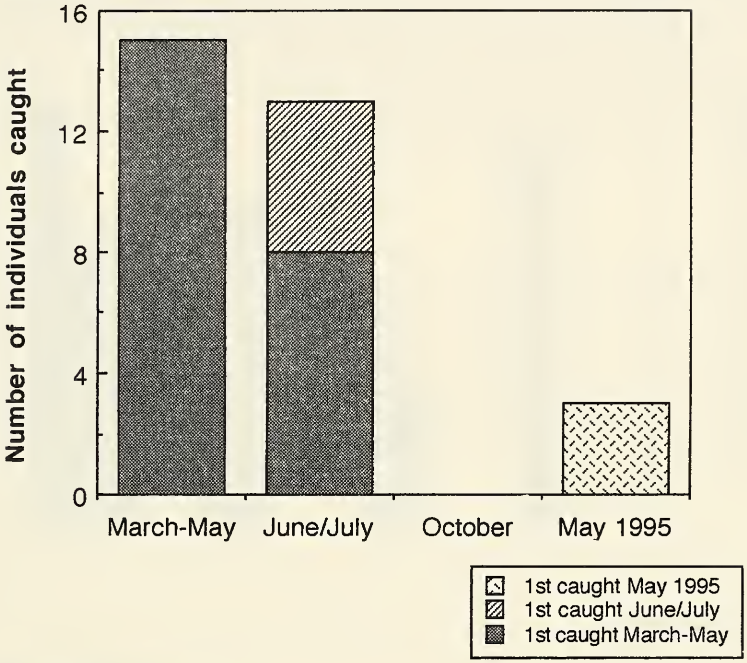


Fig. 2. Numbers of captures per 100 trap-nights for male (a) and female (b) *Antechinus stuartii* over 4 trapping periods at Royal National Park and two trapping periods at Cataract Catchment.

(a) Males



(b) Females

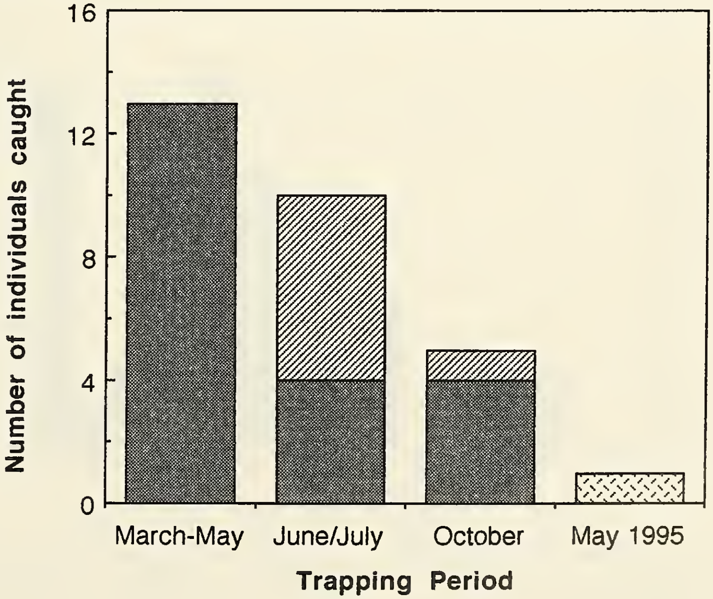
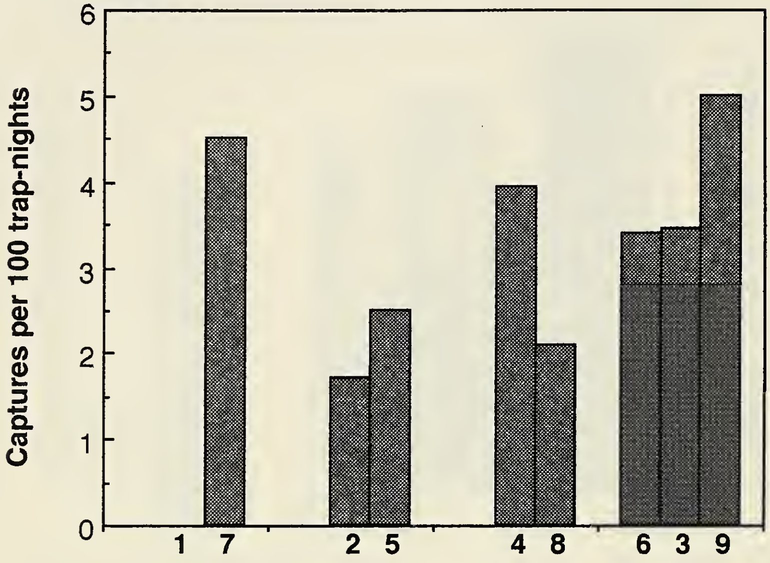


Fig. 3. Numbers of captures and recaptures of male (a) and female (b) *A. stuartii* at Royal National Park. Light hatching indicates the numbers of animals that were caught in June/July 1994 but not previously. Dark stippling in June/July and October 1994 indicates numbers of animals that had been caught in the March–May trapping period.

(a) Males



(b) Females

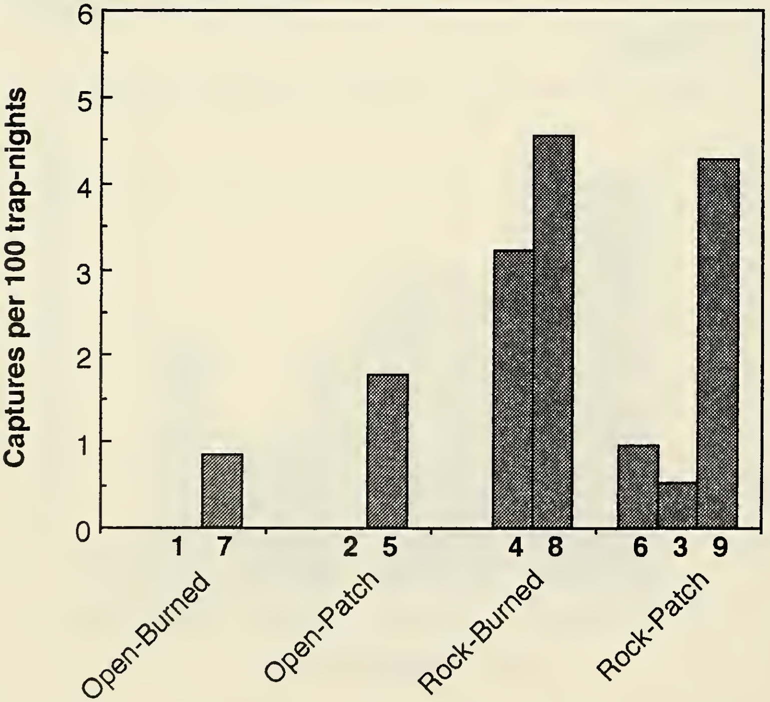


Fig. 4. Capture rates (captures per 100 trap-nights) for male (a) and female (b) *A. stuartii* caught in each of the 9 trapping grids at Royal National Park.

Movements of *A. stuartii*

The greatest distance between trap locations for a recaptured female *A. stuartii* was 260 m. Two male *A. stuartii* were trapped, in separate trapping periods, on different sides of the creek that runs between the trapping sites. These distances were sufficient to indicate that animals could move between most of the trap sites (Figure 1). However, most recaptures were within trapping grids, and spooling indicated that there was a substantial amount of movement of females along, or around, rock outcrops (Figure 5).

Use of floral resources

All 14 scat samples from animals captured in the Cataract Dam Catchment study area contained pollen of *Banksia* species, and none contained *Xanthorrhoea* pollen (Table 1): there was no *Xanthorrhoea* flowering in the Cataract area. In contrast, almost all scat samples from animals captured in both burned areas and unburned patches of vegetation at Royal National Park contained *Xanthorrhoea* pollen (during the time of *Xanthorrhoea* flowering), and most contained substantial pollen loads (Table 1). Many of the scat samples also contained *Banksia* pollen, even though there were few *Banksia* plants in flower and these were confined to the unburned patches of vegetation. It is notable that scat samples had *Banksia* and *Xanthorrhoea* pollen irrespective of whether they were from animals caught in burned areas (where *Xanthorrhoea* was flowering) or in the unburned patches (containing the only flowering *Banksia*).

The scurry marks on *Xanthorrhoea* flowering stalks were of a size and shape consistent with visits by *Antechinus* (Figure 6). A high proportion of flowering stalks showed evidence of visits by small mammals. For the ten 20 x 20m quadrats sampled, there was an average of 13.5 (±2.1 s.e.) flowering stalks. Of these, 11.2 (±1.7) had been visited. This amounts to about 85%.

TABLE 1

Banksia *and* Xanthorrhoea *pollen in scat samples from* Antechinus stuartii *at Royal National Park and Cataract Catchment. Pollen loads are classified as 0 (no grains), light (1–19 grains) and heavy (≥20 grains) in 10 scans at 100x of a faecal smear on a microscope slide.*

		Banksia pollen				*Xanthorrhoea* pollen		
	no.		% with:		no.		% with:	
	scats	0	1–19	≥20	scats	0	1–19	≥20
Royal NP unburned patches	15	33	40	27	12	0	17	83
Royal NP burned sites	20	50	40	10	10	10	50	40
Cataract Catchment	14	0	36	64	14	100	0	0

DISCUSSION

Few studies have examined in detail the population responses to fire of any animal species, though there is good evidence to suggest that (i) animals do die in fires, (ii) many animals survive the passage of a fire front, and (iii) there can be substantial post-fire mortality and/or emigration. Previous studies of mammals in Australian heathlands found that populations of several species decline to near zero soon after fire (see Fig. 3b of Fox 1982). In contrast, in this study we found that an *Antechinus* population survived well in sites that

5(a)

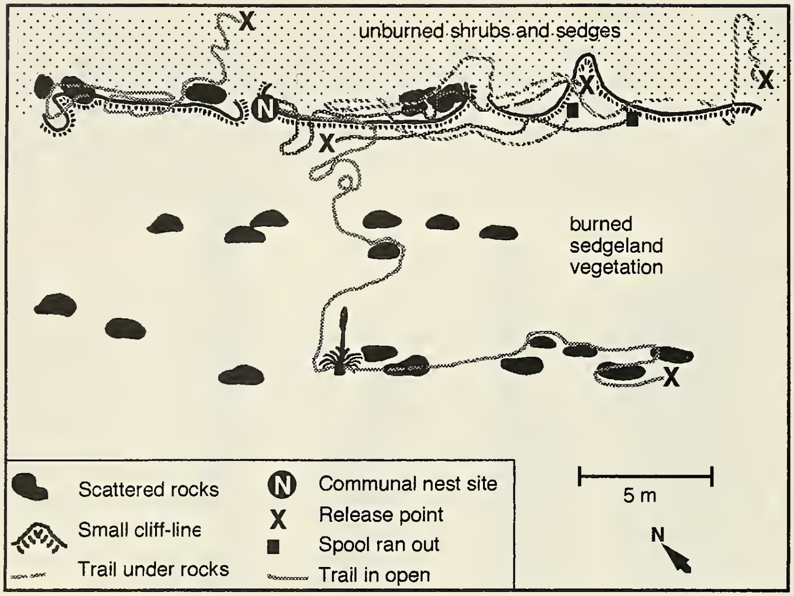
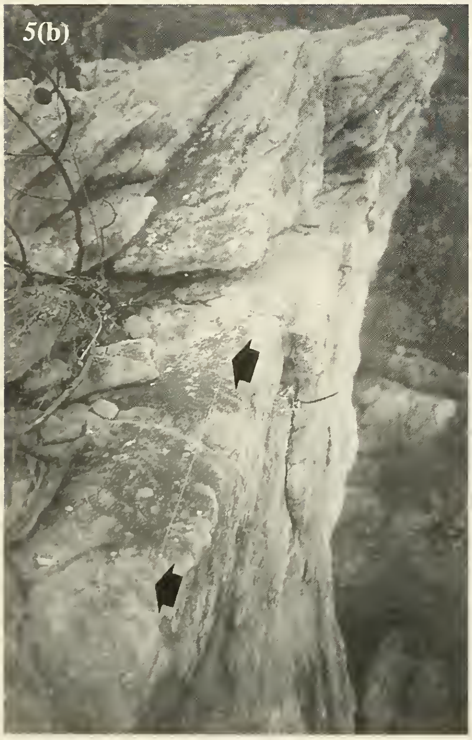


Fig. 5. (a) Map of movements of five *A. stuartii* individuals that were spooled in the area of the most extensive rock outcrop and unburned patch of vegetation — Site 9.

(b) Trail of thread (arrowed) along the edge of a sandstone outcrop in Site 9.

Fig. 6. Scurry marks, inferred to have been made by *A. stuartii*, in the powdery surface of the flowering stalks of *Xanthorrhoea media*.



were burned in the intense 1994 wildfire at Royal National Park. In the study by Newsome et al. (1975) at Nadgee Nature Reserve, there is a suggestion that *A. stuartii* survives well in some sites but not in others: in the trapping grids that were in forest or hind-dune shrubland (grids A, B, 3, 4 and 5) *A. stuartii* survived well throughout the year following the wildfire. In the swamp/heathland grids (grids 1 and 6), there was poor survival, though some animals were trapped during the year after the fire in both of these grids (Newsome et al. 1975).

Capture rates of both male and female *Antechinus stuartii* in our study were not particularly high (between 1 and 3.5 captures per 100 trap-nights) but they were comparable to the capture rates in the nearby, unburned study site of similar vegetation and fire history (Cataract Catchment). The population at Royal National Park appeared to be resident throughout 1994, as many animals captured first in March–May were recaptured in one or both of the subsequent trapping sessions. Moreover, all of the females captured in October either had young in the pouch or were pregnant. This reproduction was apparently successful, because both males and females of the next generation were captured during a limited trapping session in May 1995, although capture rates were low at this time. Perhaps this decline indicates that numbers will decline in the second year after fire, as was the case on grids 1 and 6 after the Nadgee wildfire (Newsome et al. 1975).

Although some long-distance movements occurred, identified by recapturing some animals in sites at some distance from the site of first capture, most recaptures were within trapping grids. Moreover, spooling of five *Antechinus* indicated that these animals were moving extensively along the sandstone outcrops and at least two of them were frequenting a communal nest under a ledge of sandstone.

The animals in this study appeared to be making substantial use of floral resources, presumably nectar, because pollen was present in almost all faecal samples examined. *Banksia* pollen predominated in samples from the Cataract Catchment study area: no *Xanthorrhoea* was flowering in this unburned vegetation. At Royal National Park, both *Xanthorrhoea* and *Banksia* pollen were evident in faeces, and nearly all *Xanthorrhoea* stems had scurry marks indicating visits by *Antechinus*.

We suggest that the presence of rock outcrops might have contributed to the unexpected maintenance of the *Antechinus* population in the Royal National Park heathland throughout 1994, following the wildfire. The rocky nature of the Hawkesbury Sandstone landscape may provide animals with cover from the heat of fire and also both a refuge from predators and nest sites following the fire. In other heathland and swamp sites, such as Nadgee Nature Reserve (Newsome et al. 1975) or Myall Lakes (Fox 1982), more uniform habitat may contain fewer refuges. In addition, the timing of the wildfire at Royal National Park was such that *Xanthorrhoea media* flowered in the winter after the fire, providing a high-energy food source (nectar). We speculate that a fire later in the year may have resulted in a 1-year delay in the burst of flowering, perhaps causing a more severe drop in *Antechinus* numbers. It remains to be seen what might happen in the second winter after the fire, if there is little flowering of *Xanthorrhoea* (Gill 1981, Whelan 1995).

In conclusion, we argue that experimental studies are badly needed to test the importance of cover, nest sites and a readily available winter energy supply, in the maintenance of *A. stuartii* populations in burned heathland. This study suggests that the timing of a fire may be crucial in determining the population dynamics of small-mammal populations indirectly, via the impact of fire season on the flora.

REFERENCES

Carthew, S.M. (1993). An assessment of pollinator visitation to *Banksia spinulosa*. *Australian Journal of Ecology* **18**, 257–268.

Cheal, D. (1983). The effects of fire on animal life. *Trees and Victoria's Resources*. **25**, 12–13.

Christensen, P.E.S. (1980). The Biology of *Bettongia penicillata* Gray 1937 and *Macropus eugenii* (Demarest 1917) in Relation to Fire. *Forests Department of Western Australia Bulletin* 91.

Christensen, P.E.S. and Kimber, P.C. (1975). Effect of prescribed burning on the flora and fauna of south-west Australian forests. *Proceedings of the Ecological Society of Australia* **9**, 85–106.

Cockburn, A. and Lazenby-Cohen, K.A. (1992). Use of nest-trees by *Antechinus stuartii*, a semelparous, lekking marsupial. *Journal of Zoology* **226**, 657–680.

Dickman, C.R. (1983). *Competition Between the Dasyurid Marsupials* Antechinus stuartii *and* Antechinus swainsonii. PhD Thesis, Australian National University.

Fox, B.J. (1982). Fire and mammalian secondary succession in an Australian coastal heath *Ecology* **63**, 1332–1341.

Fox, B.J. and McKay, G.M. (1981). Small mammal responses to pyric successional changes in eucalypt forest. *Australian Journal of Ecology* **6**, 29–41.

Gill, A.M. (1981). Adaptive responses of Australian vascular plant species to fires. In 'Fire and the Australian Biota'. (Eds. Gill, A.M., Groves, R.H., and Noble, I.) pp. 243–272 (Australian Academy of Science: Canberra).

Goldingay, R.L., Carthew, S.M. and Whelan, R.J. (1991). The importance of non-flying mammals in pollination. *Oikos* **61**, 79–87.

Green, K. (1989). Altitudinal and seasonal differences in the diets of *Antechinus swainsonii* and *A. stuartii* (Marsupialia: Dasyuridae) in relation to the availability of prey in the Snowy Mountains. *Australian Wildlife Research* **16**, 581–592.

Hall, S. (1980). The diets of two coexisting species of *Antechinus* (Marsupialia: Dasyuridae). *Australian Wildlife Research* **7**, 365–378.

Hemsley, J. (1967). 'Bushfire – S.E. Tasmania'. (National Parks and Wildlife Service: Tasmania).

Higgs, P. and Fox, B.J. (1993). Interspecific competition: a mechanism for rodent succession after fire in wet heathland. *Australian Journal of Ecology* **18**, 193–201.

Hyett, J. and Shaw, N. (1980). 'Australian Mammals: A Field Guide for New South Wales, Victoria, South Australia and Tasmania'. (Nelson: Melbourne).

Newsome, A.E., McIlroy, J. and Catling, P. (1975). The effects of an extensive wildfire on populations of twenty ground vertebrates in south-east Australia. *Proceedings of the Ecological Society of Australia* **9**, 107–123.

Recher, H. and Christensen, P.E.S. (1981). Fire and the evolution of the Australian biota. In 'Ecological Biogeography of Australia' (Ed. A. Keast) pp. 137–162 (Junk: Dordrecht).

Whelan, R.J. (1995). 'The Ecology of Fire'. (Cambridge University Press: Cambridge).